Updated Inventory of Titan Organics

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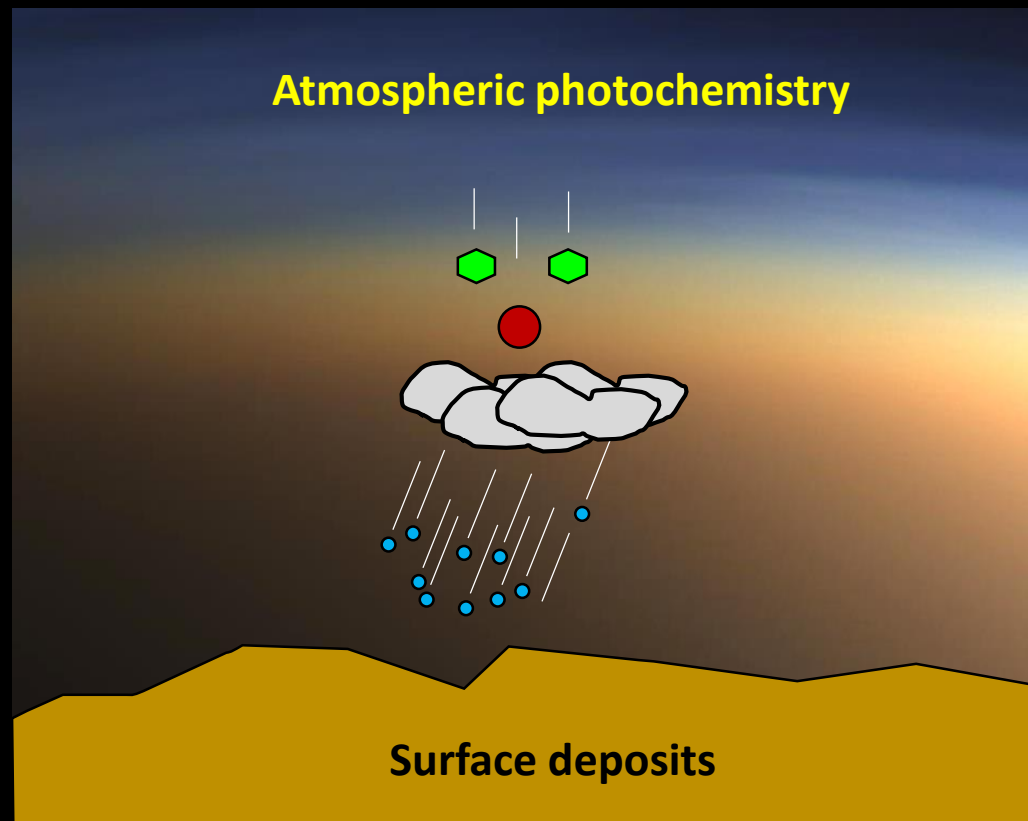
Photochemical production

x Time

?

=

Observed volume

Atmospheric photochemistry

Surface deposits

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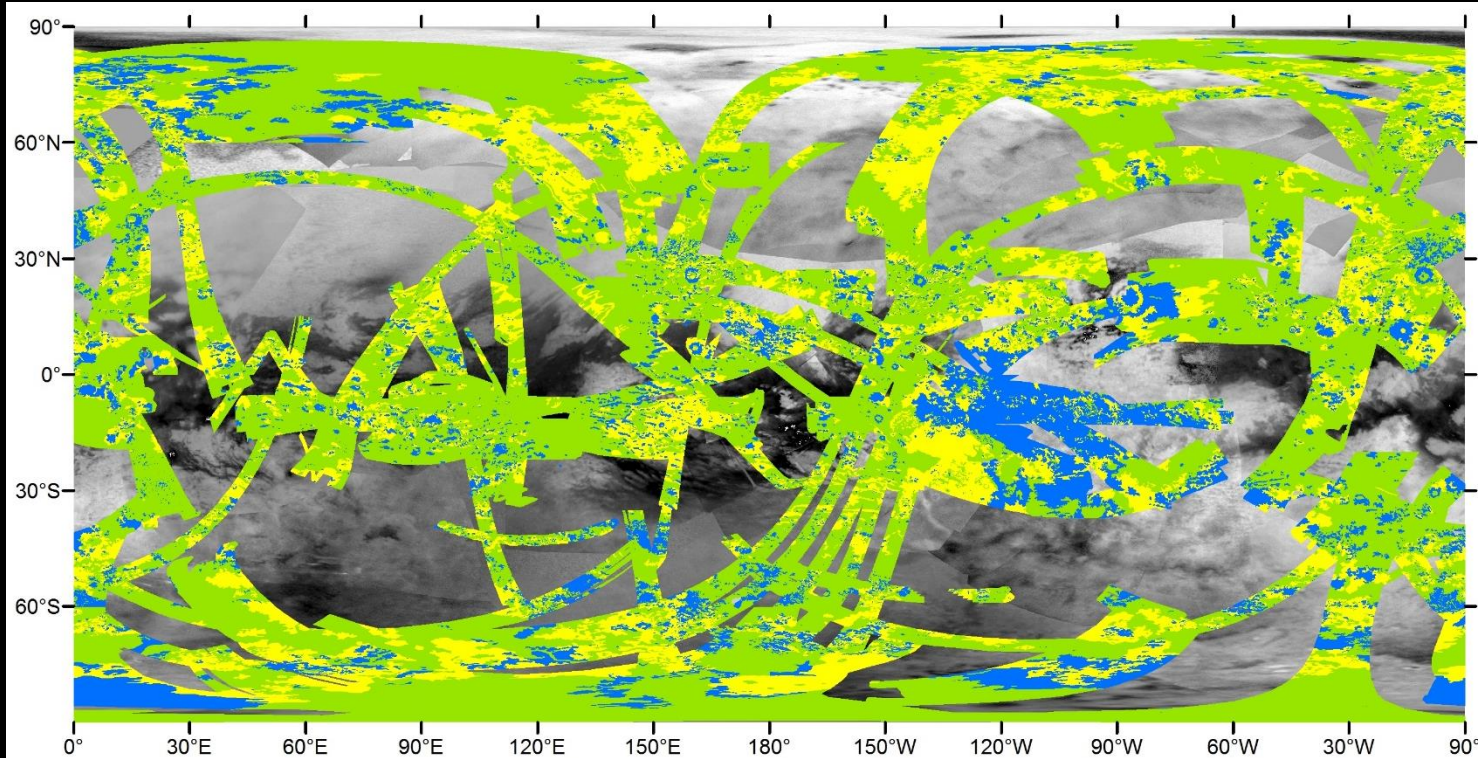[5] LATMOS/IPSL, UVSQ Université Paris-Saclay, France.
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OrganicWorldTitan

Mapping and identification of materials consistent with organic units [→spatial area] [1]

Global map of SAR-mapped terrain units colorized by likely composition

3000 km

Terrain classes	Areal% [2]
Plains	65.05%
Dunes	17.48%
Mountains	14.09%
Lakes	1.49%
Labyrinths	1.46%
Craters	0.42%

Microwave emissivity consistent with:

Organics   Not sure   Water ice

[1] Malaska et al., DPS (2016).
[2] Lopes et al., submitted.

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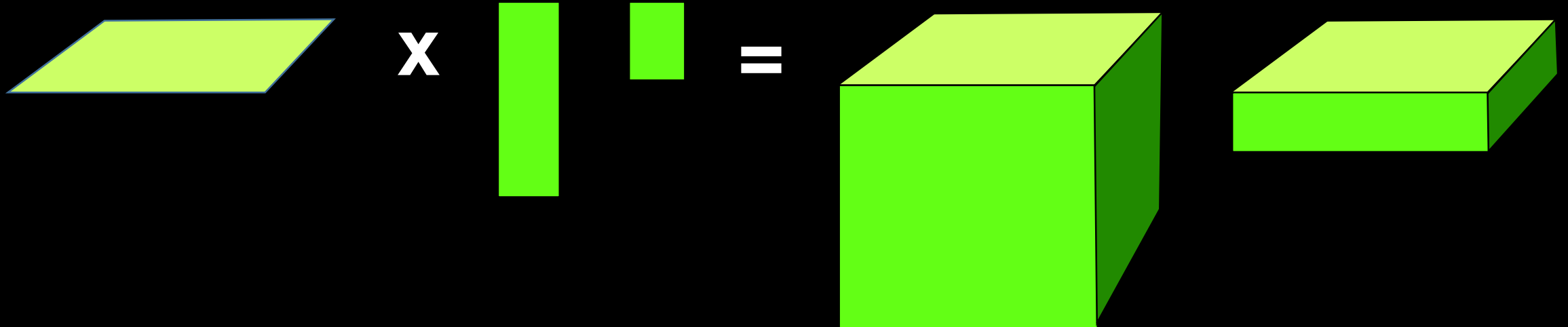# Method of estimate

Area x thickness = volume

Area   Organic Thickness

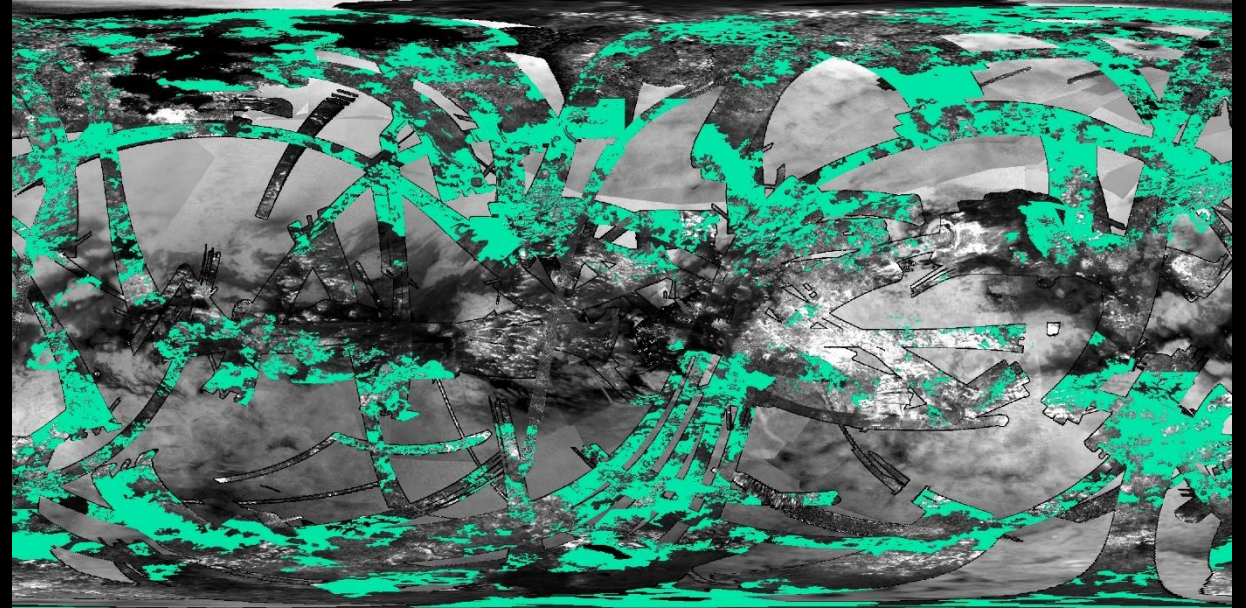Hi   Lo

Organic-rich Rich scenario

Organic-poor Lean scenario

Organic inventory on Titan: Plains

Plains cover 65% of Titan
Many types of plains

Undifferentiated Plains dominant
This unit covers 19.5% of Titan

Undifferentiated plains high emissivity → likely organic

Global map of SAR-mapped undifferentiated plains

3000 km

Minimum thickness would be minimum emissivity cover depth = 1 m
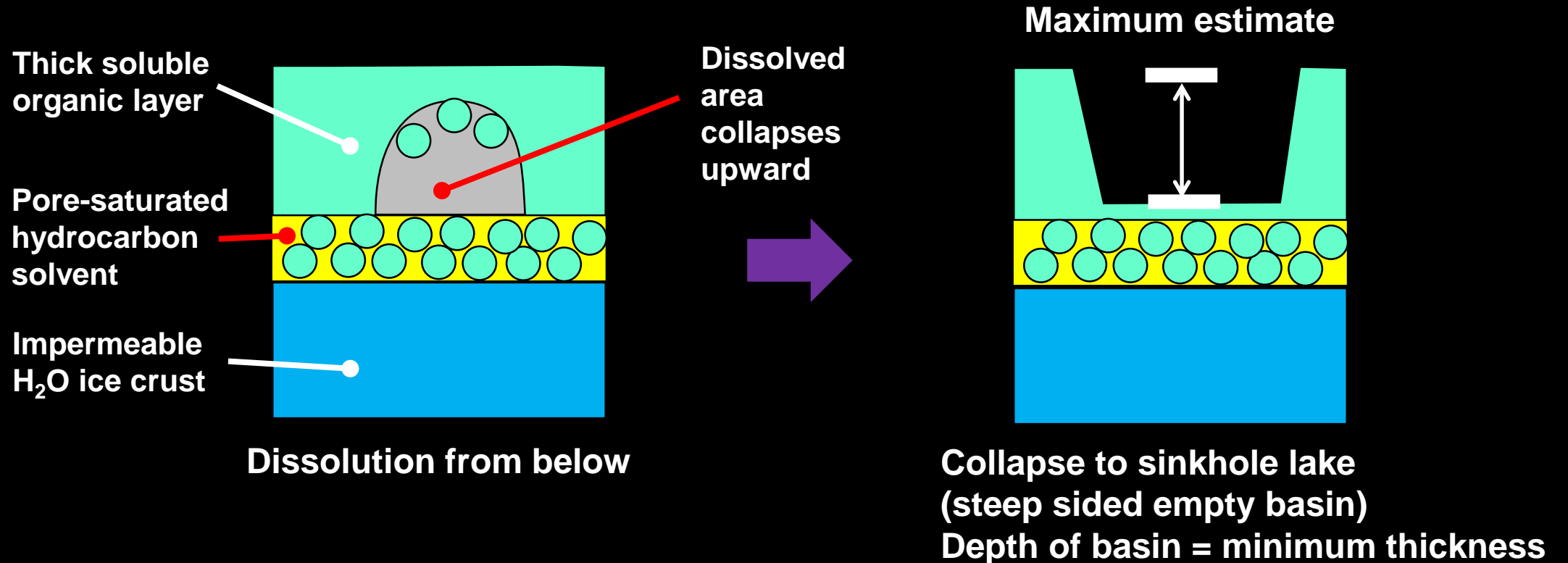**What is maxmum estimate that is grounded in observations?**

How do we estimate the thickness of the plains?

One approach:

Use observations of steep-sided empty lakes

**Assume they all formed from sinkhole dissolution through an organic layer**

Maximum thickness is observed empty basin depth

Thick soluble organic layer

Dissolved area collapses upward

Pore-saturated hydrocarbon solvent

Impermeable H_2O ice crust

Dissolution from below

Maximum estimate

Collapse to sinkhole lake (steep sided empty basin)
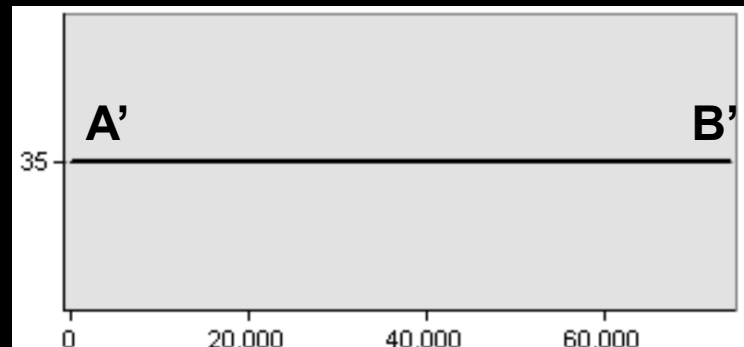**Depth of basin = minimum thickness**

Determining depth from surrounding terrain of empty lake basins Example with altimetry (see: Hayes et al., 2017)

Altimetry data (Corlies et al., 2017)
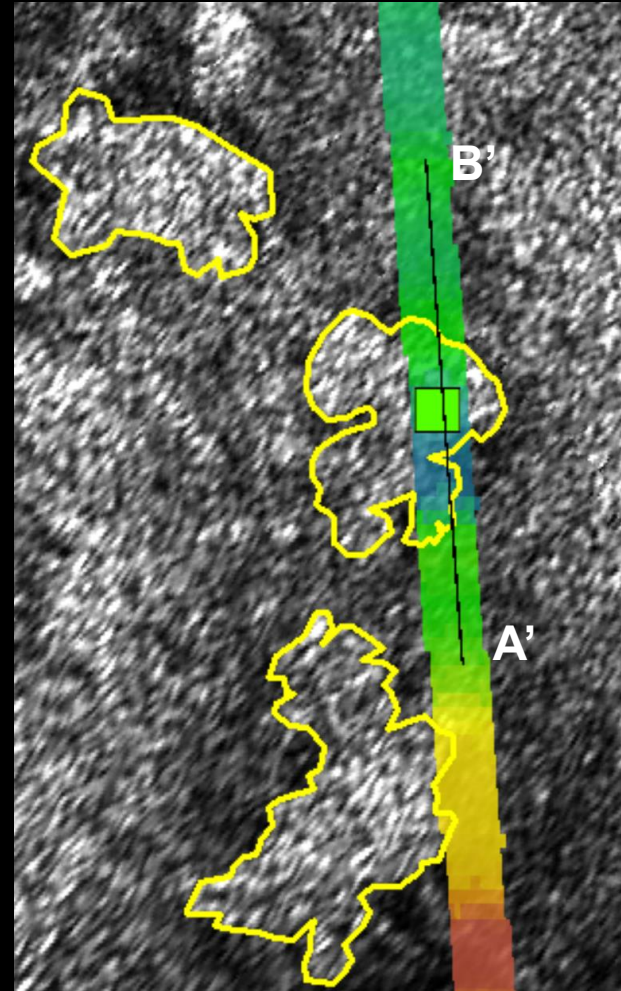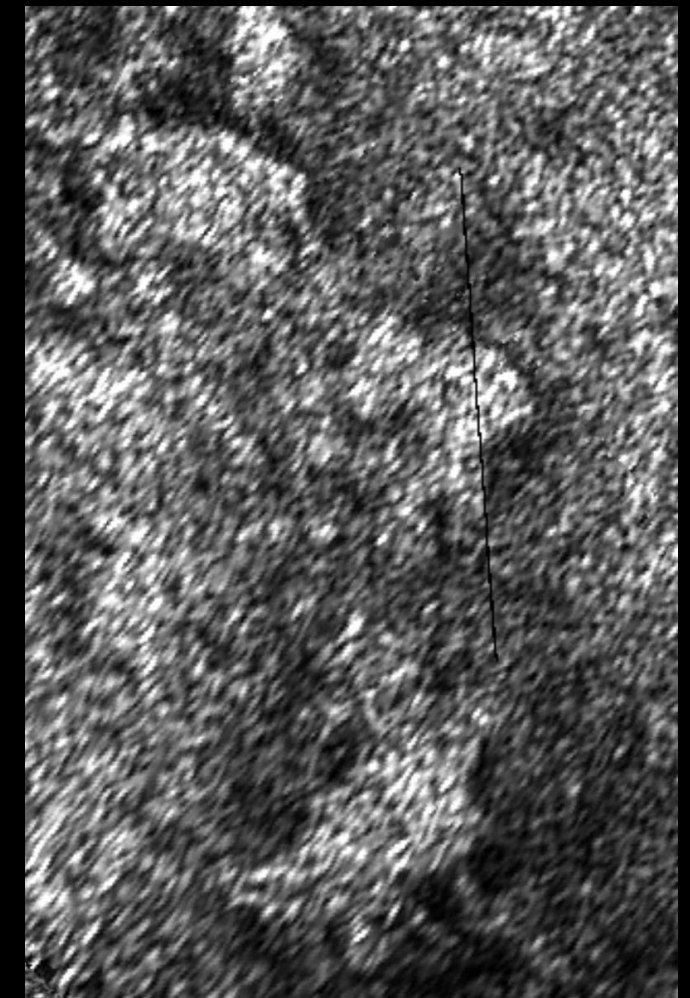

ca. 90 m
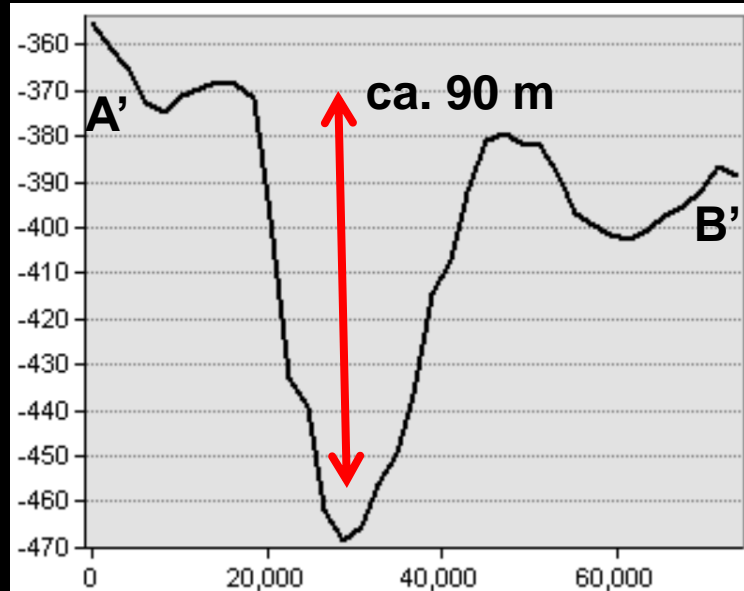
Alitmetry error (Corlies et al., 2017)

Unnamed lacuna 63 km SW of Atitlán Lacus (68.03°N, 240.4°W)
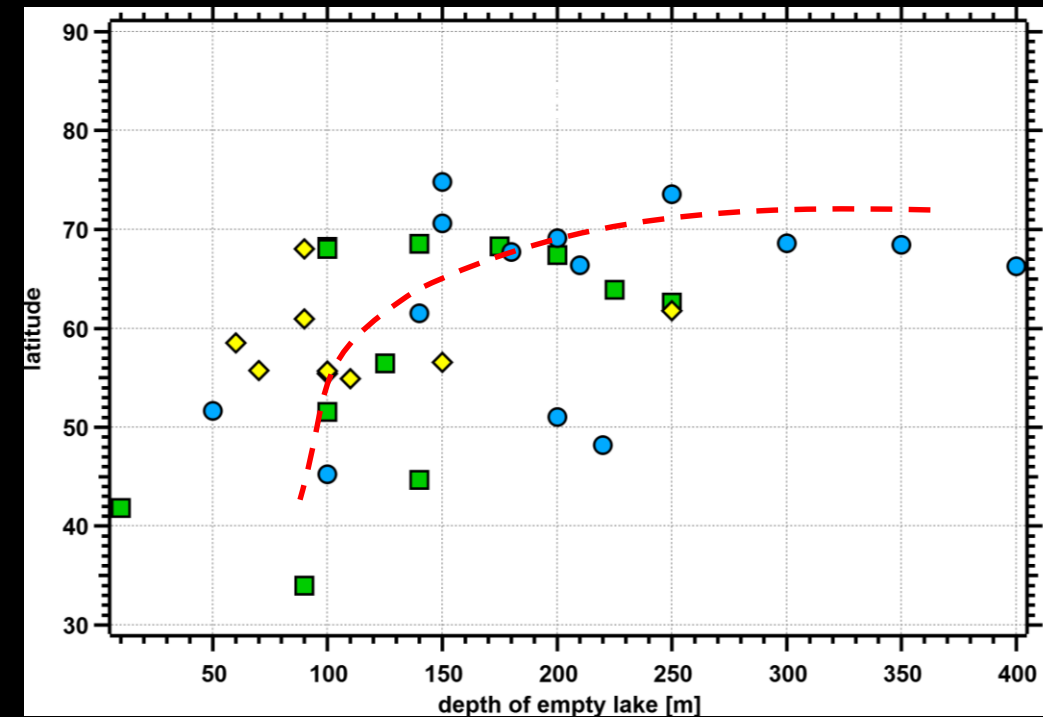

SAR image with outline and SARTopo

Unannotated SAR

Plains deposit depths

Possible trend of shallower depths at lower mid-latitudes [1]

Minimum case (mid lat depth)

⬤	**Undifferentiated plains**	**100 m**
◆	**Scalloped plains**	**100 m**
⬛	**Variable plains**	**100 m**

[1] Polar thickness = 200 m from empty lake depths in Hayes et al., 2017 and corroborated by this analysis   7

Titan Plains Units Inventory – terrain unit types

	Plains unit	Areal coverage [E6 km²]	Effective depth [Hi-Lo] [m]	Organic rich estimate [E5 km³]	Organic poor estimate [E5 km³]
Thick organic	Undifferentiated	16.2	100 – 1	16.2	0.2
	Scalloped	2.1	100 – 1	2.1	0.02
	Dark irregular	1.1	100 – 1	1.1	0.01
	Undivided dark	3.3	100 – 1	3.3	0.03
	Undivided	20.2	100 – 1	20.2	0.2
??	Variable featured	9.5	100 – 0.1	9.5	0.01
	Dissected	0.1	100 – 0.1	0.1	0.0001
	Bright lineated	0.08	100 – 0.1	0.08	0.0008
Thin organic	Bright streak-like	0.9	100 – 0	0.9	0
	Bright alluvial	0.1	1 – 0	0.01	0
	Gradational	0.5	0	0	0

Plains total

Rich scenario	Lean scenario
53.5E5 km³	0.4E5 km³

Organic inventory on Titan: Dunes

2nd most dominant terrain class on Titan
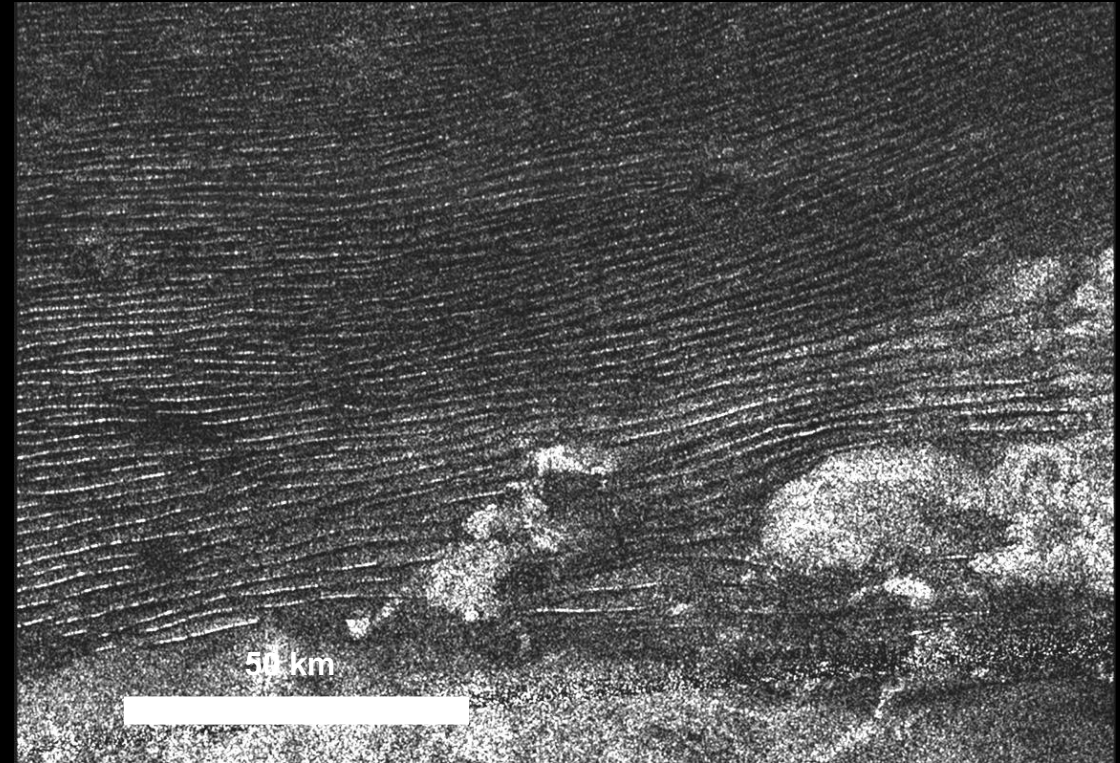(mostly exist as linear dune seas or ergs)
Area coverage: 17.48%
Radiometrically high emissivity
Consistent with organics

Surface area: 14.5E7 km^2

Effective thickness: 30 m – 12 m from [1]

Belet Sand Sea, [9°S, 266°W]

Dunes total	
Rich scenario	Lean scenario
4.4E5 km^3	1.8E5 km^3

[1] Rodriguez et al., Icarus 230 (2014) 168-179.
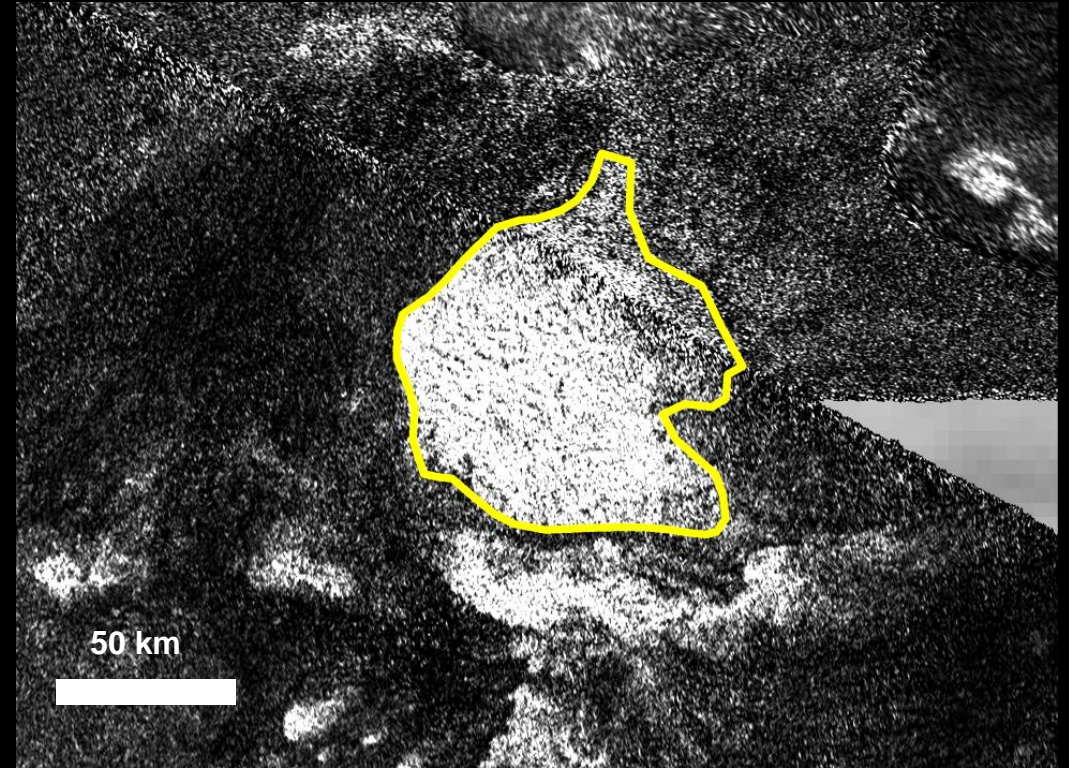
Organic inventory on Titan: Mountains

High backscatter; rugged
Very low microwave emissivity
Consistent with water ice / volume scatter

Assume thin < 1m to zero organic cover

Surface area: 14.09% total surface
 = 11.6 E6 km^2

Effective thickness: 1 m – 0 m

Major terrain unit, but not organic reservoir

Gandalf Colles, [14.3°N, 209.7°W]

Mountains total	
Rich scenario	Lean scenario
0.1E5 km^3	0 km^3

Organic Lake inventory

Minor unit on Titan: 1.49% of total surface

Hydrocarbons and dissolved N^2

Use volume estimate from Hayes et al. [1]
0.7 E5 km^3 liquid

Assume average composition of 30% ethane/hydrocarbon, 10% N_2, rest condensed methane.

0.07E5 km^3 dissolved N_2 (ignore)
0.44E5 km^3 methane (condensed)
0.19E5 km^3 ethane (from production)

[1] Hayes, AREPS 44 (2016), 57-83.

Ontario Lacus, [72°S, 185°W]

Lakes total
Rich scenario & Lean scenario
0.6E5 km^3
0.2E5 km^3 ethane

Organic inventory on Titan: Labyrinths

Minor unit on Titan, but thick
Areal coverage: 1.46%

High microwave high emissivity
Consistent with organic plateaux

Locally elevated (500 m) and dissected
Account for terrain dissection/removal

Surface area: 1.2E6 km^2
Average elevation of plateaux: 277 m [1]
Average %removed: 56%
Effective thickness: 122 m
Estimated volume : 1.5E5 km^3)

[1] Malaska et al., in prep.
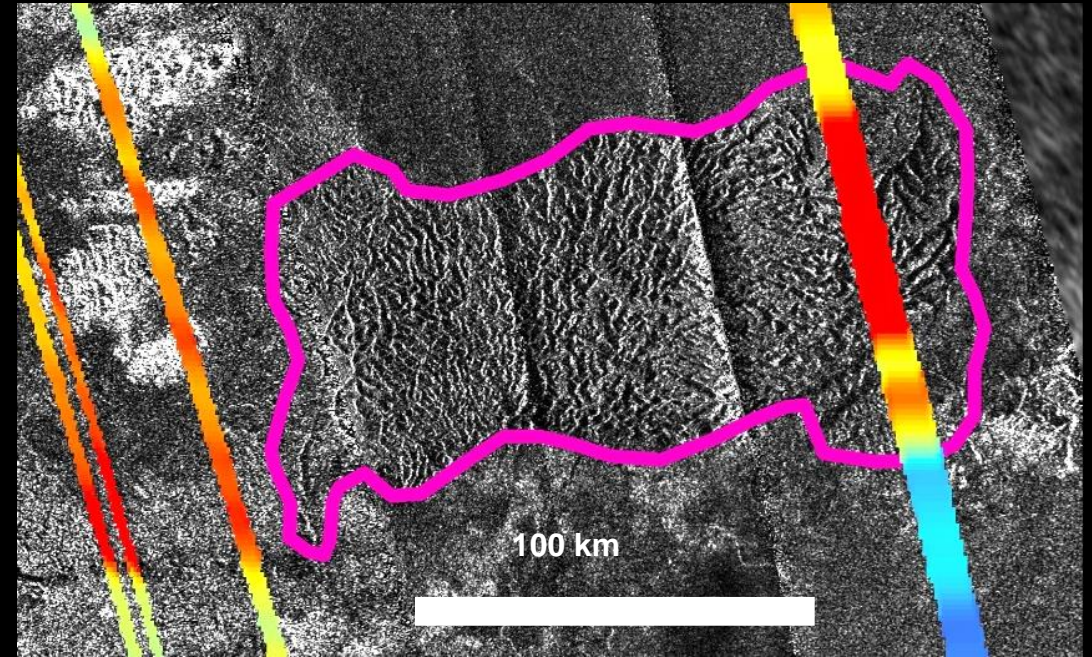
SARTopo and Katain Labyrinthus, [52.4°N, 348.9°W]
Katain is approximately 630 m above average local terrain

630 m

Labyrinth total
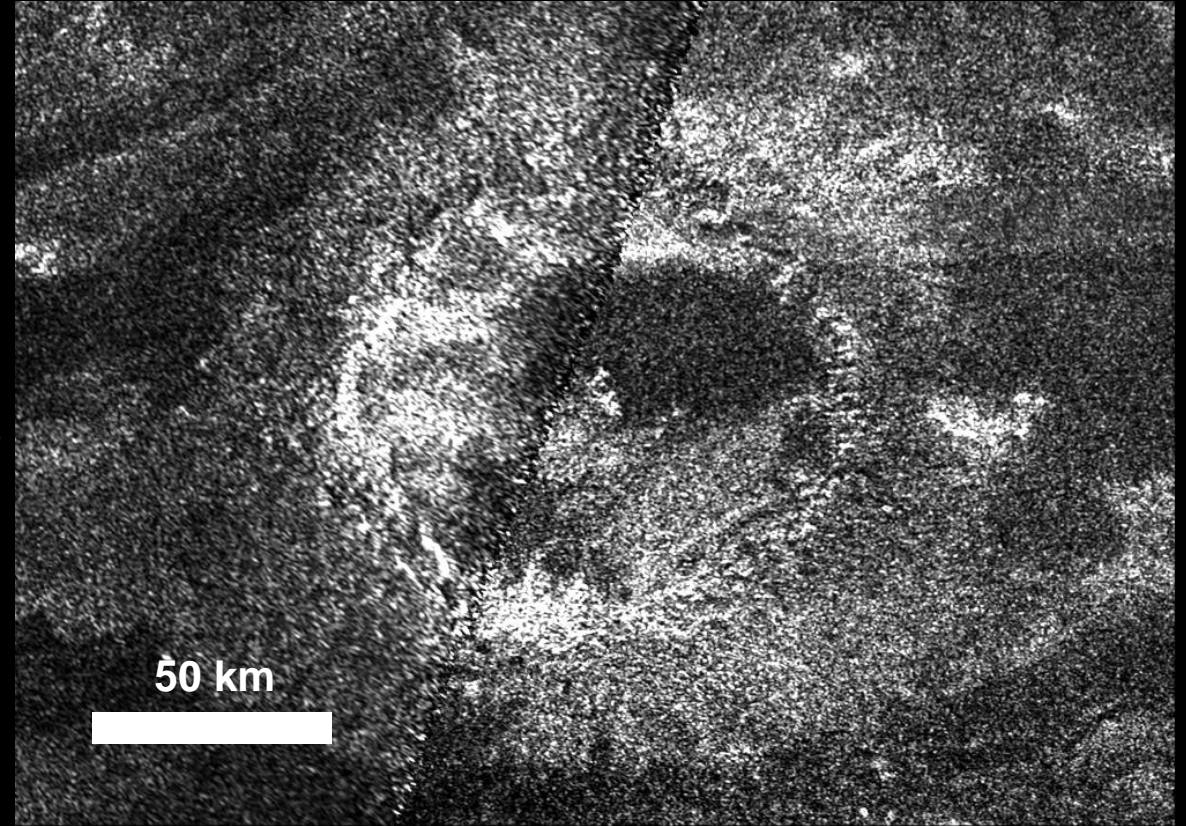**Rich scenario & Lean scenario**
1.5E5 km^3

Organic inventory on Titan: Craters

Very minor unit on Titan
Areal coverage: 0.42%

Very Low microwave emissivity
Consistent with volume scattering ice

Treat crater rim, central peak, crater ejecta , crater fill 1 as water ice
(1 m – 0 m thick organics)

Treat crater ejecta, crater fills 2 – 4 as Variable featured plains
(25 – 1 m thick organics)

Afekan Crater [25.7 N, 160 W]

Craters total

Rich scenario	Lean scenario
$0.01E5\ km^3$	$5\ km^3$!!!

50 km

Organic deposit totals

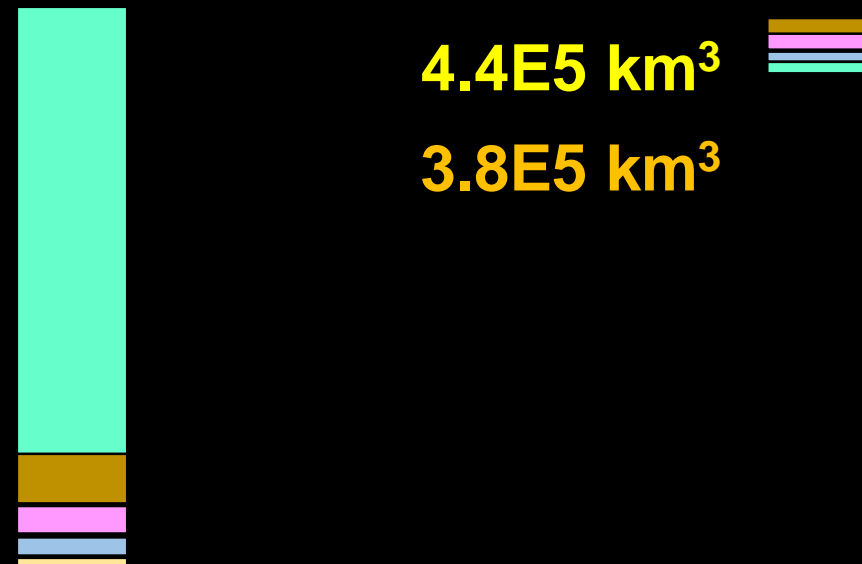| Terrain classes	Rich scenario volume [E5 km³]	Lean scenario volume [E5 km³]
Plains	53.5	0.4
Dunes	4.4	1.8
Mountains	0.1	0
Lakes	0.6 (0.2 ethane)	0.6 (0.2 ethane)
Labyrinths	1.5	1.5
Craters	0.01	0

TOTAL Organics — 60.3E5 km³ — 4.4E5 km³

TOTAL Solid organics — 59.6E5 km³ — 3.8E5 km³

Global average organic depth: Solids and liquids

	Organic-rich scenario	Organic-lean scenario
TOTAL Solid organics	**$59.6E5$ km^3**	**3.8 km^3**
Average solid organic depth	**71.8 m**	**4.4 m**
TOTAL ethane	**$0.2E5$ km^3**	**$0.2E5$ km^3**
Average ethane depth	**0.2 m**	**0.2 m**
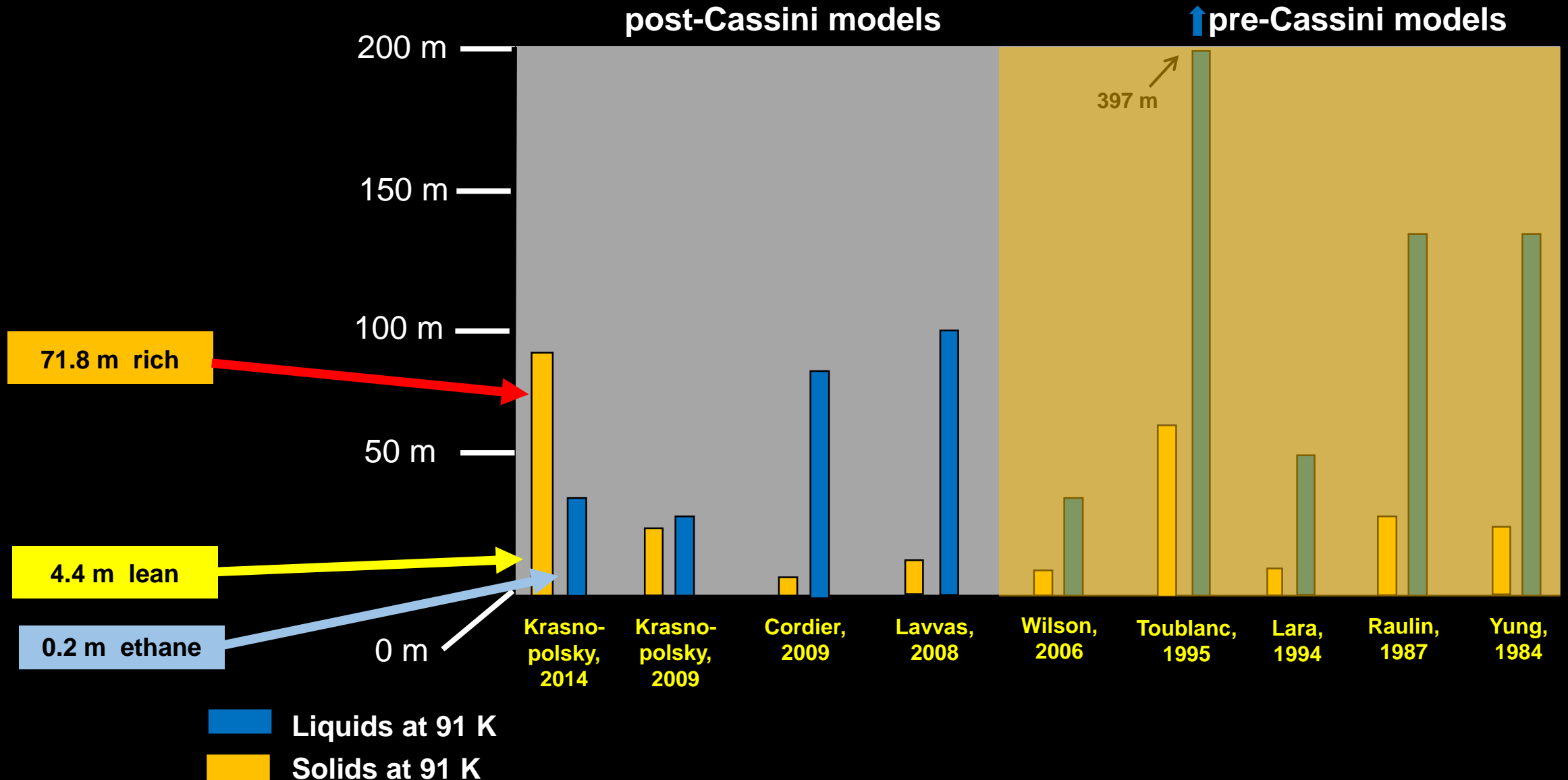
Conclusions and Implications

Organic amount in plains units is biggest "wild card" estimate

Organic-rich scenario requires at least 1 Gyr solids production in most aggressive model

Organic-lean scenario can be done ca. 1 Gyr production in all models

Much more solids than liquids vs. predictions
Ethane is being underproduced (or secreted away)